Preliminary Results from a Pan-CMIP OSSE

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May 11, 2016

CLARREO Fall Science Team Meeting

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Outline

- Update on Strengthening International Collaborations.
- Overview and goals of a pan CMIP OSSE capability.
- Pan CMIP OSSE development update.
  - First phase models.
  - Vertical interpolation.
- Preliminary results from time-series analysis
- Summary.
- Discussion.

International Collaborations

- Building off PNAS (LBNL), GRL (Umich), and JC (Umich) papers on science value of surface emissivity measurements, collaboration with UK partners strengthened through a funded NERC proposal.

- Investigation will analyze CIRCCREX data over Greenland and the Denmark Strait and retrieve far-IR surface emissivity over ice-sheet and ocean.
  - Compare with calculations in emissivity database.

- Investigation will quantify ice-emissivity feedback within models.
  - Preliminary diagnosis using kernel techniques for CESM1.2 is +0.07 $W/m^2/K$ (~1/3 ice albedo feedback), but is state-dependent and will decrease with increasing H_2O.
  - Framework for online feedback analysis within CESM has been built.

- Investigation will improve understanding of the controls on the polar radiative energy budget.

Pan CMIP5 OSSE Capability

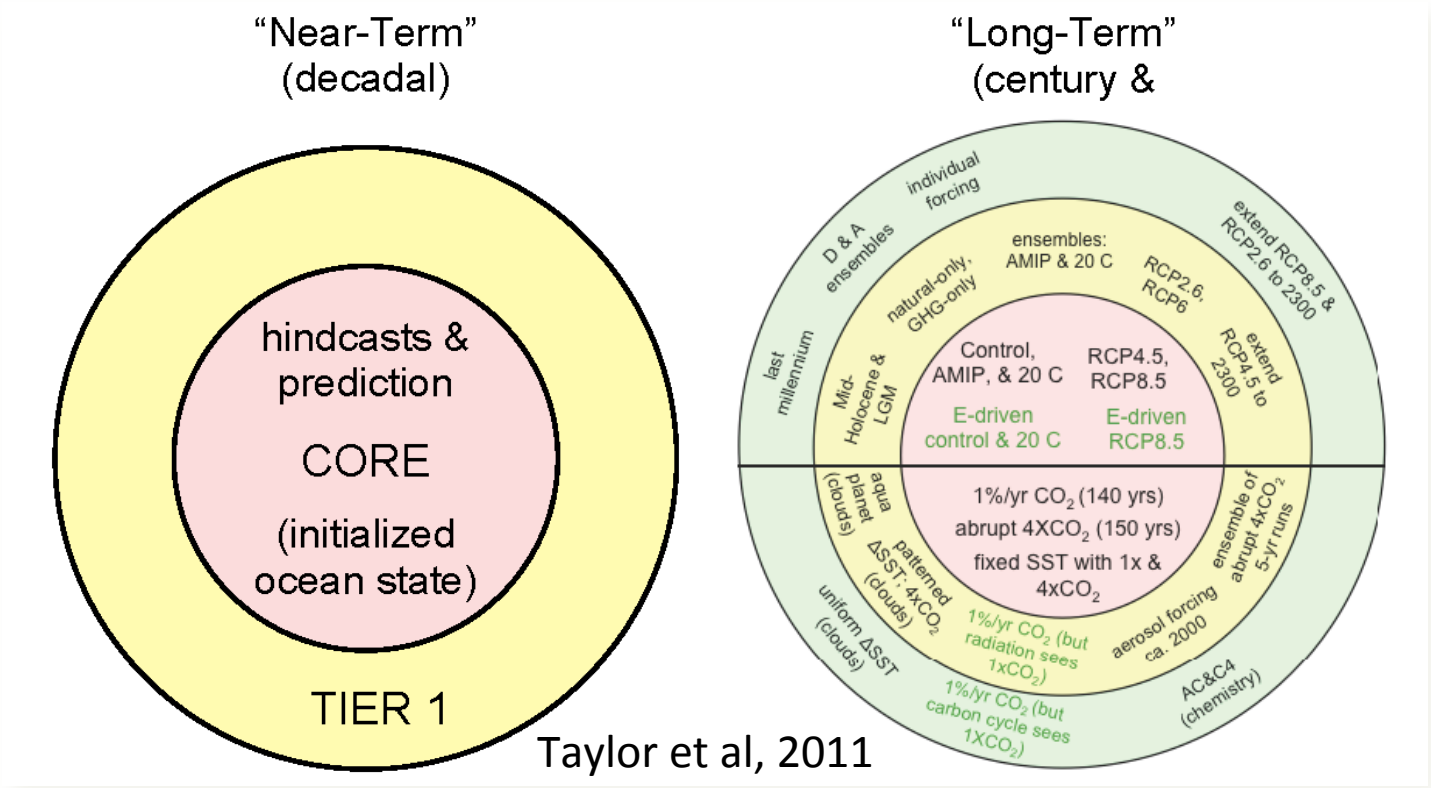
•At Spring 2015 CLARREO meeting, Berkeley group received guidance to focus on development of a pan CMIP5 OSSE capability in support of CLARREO.

•Berkeley group will build off current OSSE, develop model-agnostic OSSE capability for SW reflectance and LW radiance for CMIP5 and CMIP6 models.

•Goals:

- Determine relationship between model ECS and pan-spectral trends.
- Establish pan-spectral variability across a broad range of climate models, with an eye towards observational constraint.
- Support Decadal Survey 2017-2027 discussion.

The CMIP5 climate simulation protocol



Taylor et al, 2011

- The Coupled Model Intercomparison Protocol (CMIP5) is the basis for AR5.
- It includes a new set of simulations for the historical record: 1850 - 2005.

Progress Report

- First Phase Models Overview.
- Data Acquisition.
- Horizontal Interpolation.
- Vertical Interpolation.
- Preliminary Results.
- Execution on NAS facilities.

First Phase Models

•Model vertical-coordinate idiosyncrasies and data availability from Earth System Grid and mirroring servers have limited the feasible range of models for the first phase of the pan CMIP OSSE.

- First phase contains nearly complete range of diagnosed ECS across full ensemble.

Model Name	Diagnosed ECS (°K/2xCO2)
CESM1-CAM5	4.10
CanESM2	3.69
MIROC-ESM	4.67
MIROC5	2.72
MRI-CGM3	2.60
MRI-ESM1	2.11
inmcm4	2.08

Data Acquisition

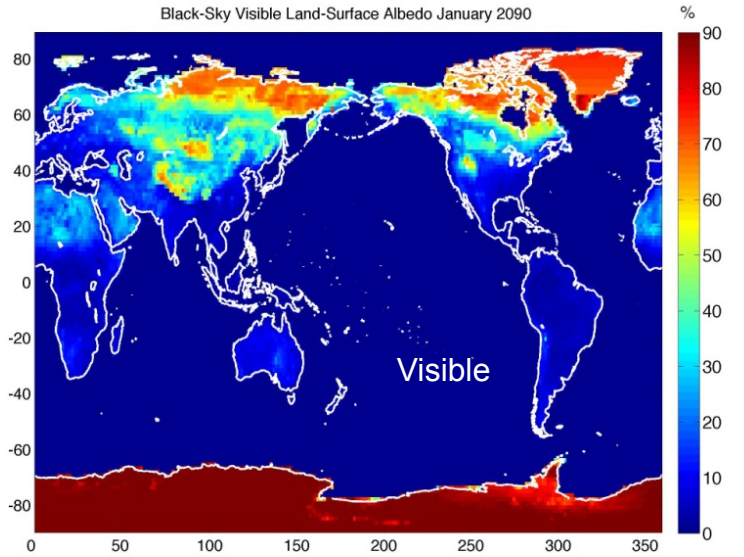
- Thermodynamic and condensate profiles downloaded from Earth System Grid and its mirrors.

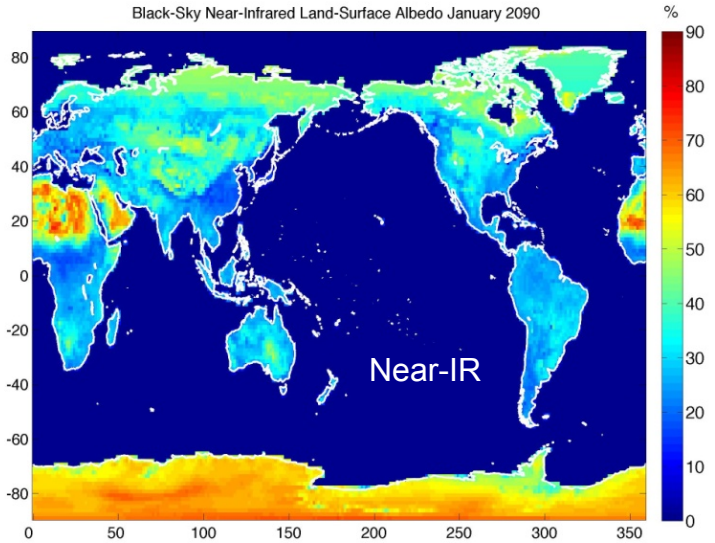
- MODIS 16-day averages of 7 bands of BRDF and albedo, and 6 bands of emissivity gathered for 2003-2014.

- Model-agnostic NCL and Matlab routines developed to concatenate fields into appropriate input files for OSSE.
  - If you expect to work with multiple CMIP5 or CMIP6 fields, these routines will save you time.

Boundary Condition Horizontal Interpolation

- Key component of Berkeley's pan-spectral OSSE is surface boundary conditions built off of MODIS land-surface products.
- Gridding required for MODIS Climate Modeling Grid (CMG) data for each model's horizontal resolution.
  - Highly computationally-intensive, but parallelizable.





Vertical Interpolation

•OSSE is now model-agnostic for horizontal resolution, but it is less flexible for vertical resolution and inflexible on using layers, instead of levels.

•Vertical interpolation routines are required for thermodynamic and condensate profiles.

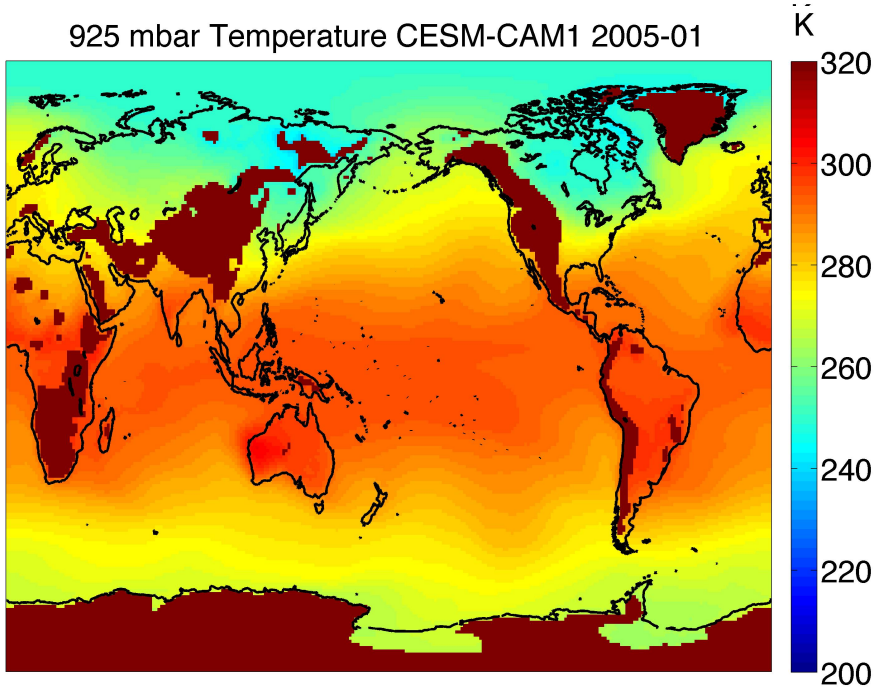
- Routines need to be mathematically stable and mass-conserving with no edge cases.
- Central challenge is that enormous heterogeneity used for vertical grids in climate model output.

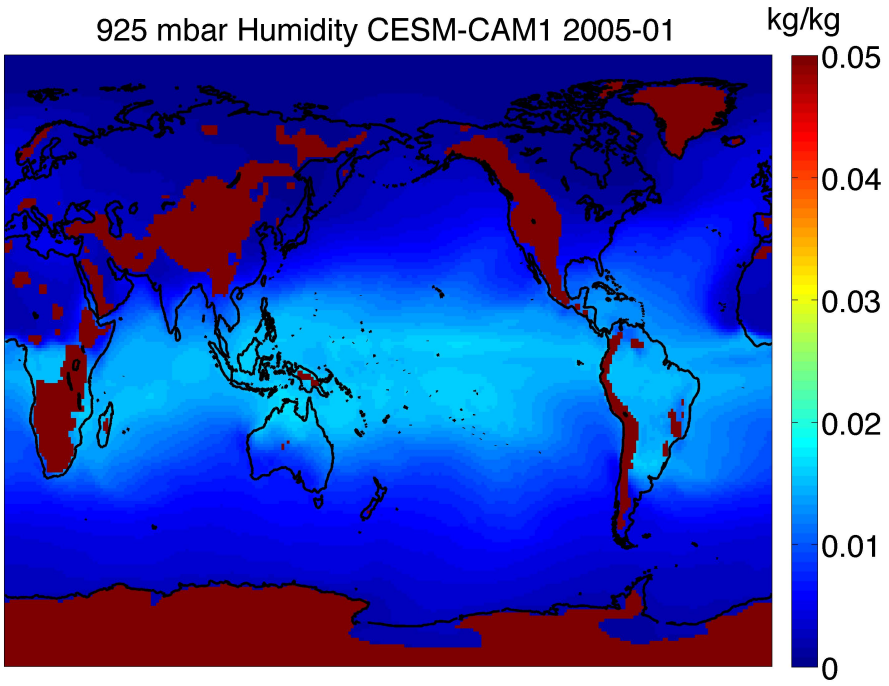
Heterogeneous Vertical Grids Used in CMIP5

- Input to OSSE is CMIP5 climate model output assessed in the IPCC AR5.
- Difficulties in building complete thermodynamic + cloud profiles for OSSE from CMIP5:
  - Hi-res. thermodynamic profiles mapped to lo-res mandatory pressures
  - Hi-res. Cloud data is left on native model grid (differs model to model)
- We tried two alternates for interpolating these data to common grid:
  - Interpolate clouds to mandatory pressures
  - Interpolate thermodynamic profiles back to native model clouds
- Both interpolation schemes were strictly mass conservative.
- 1st scheme failed, 2nd scheme worked, and we are using 2nd scheme.

Vertical Interpolation Interpolating Clouds to Mandatory Levels -- Reason for Failure

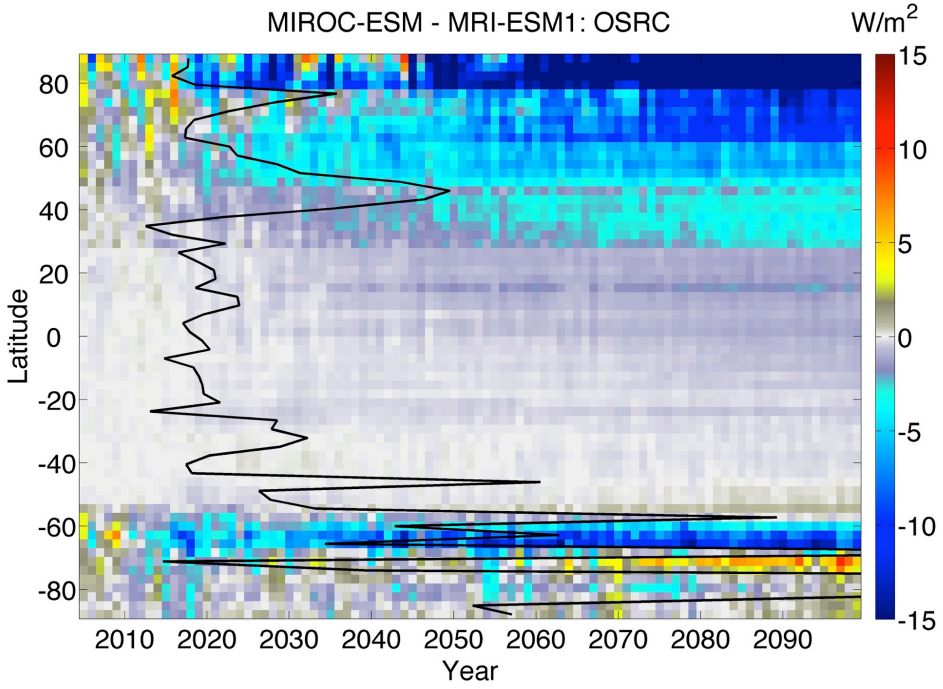
- Thermodynamic profiles = unphysical fill values where surface pressure less than mandatory level pressure in CMIP5 archive.

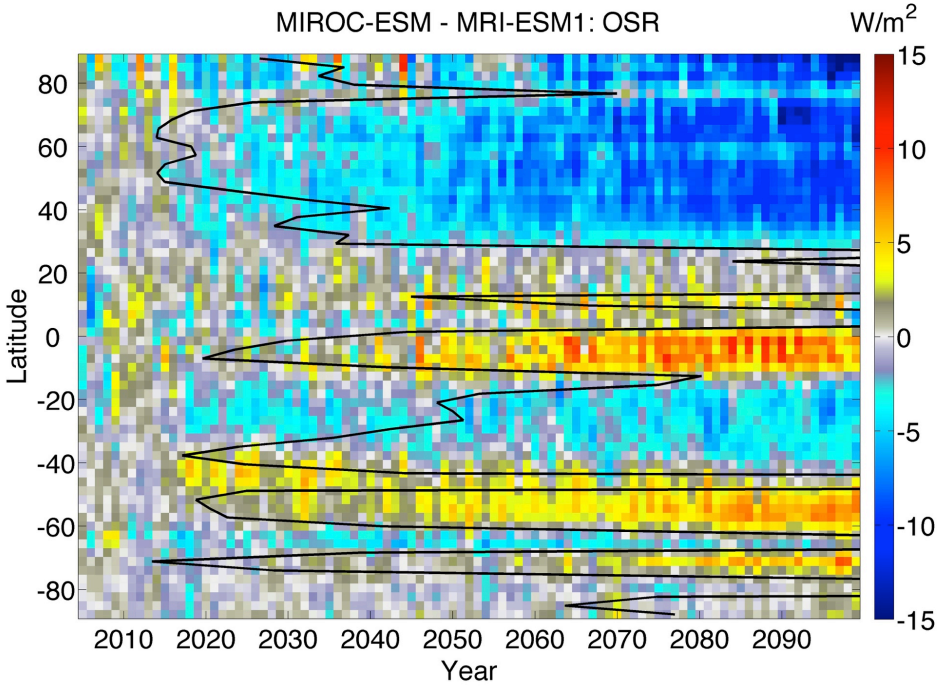




Model Differentiation: MIROC-ESM (4.7°) − MRI-ESM1 (2.1°)

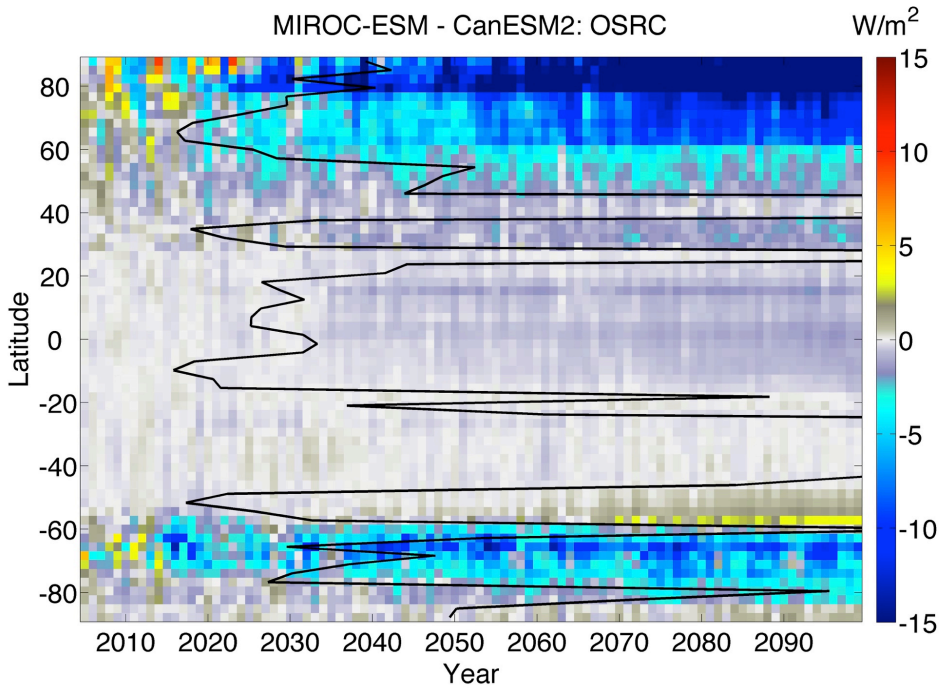
- MIROC-ESM and MRI-ESM1 span the range of ECS diagnosed for CMIP5.
- Under RCP8.5, perfect broadband measurements starting in 2005 can begin to exclude one of these models with 15 years' of data.

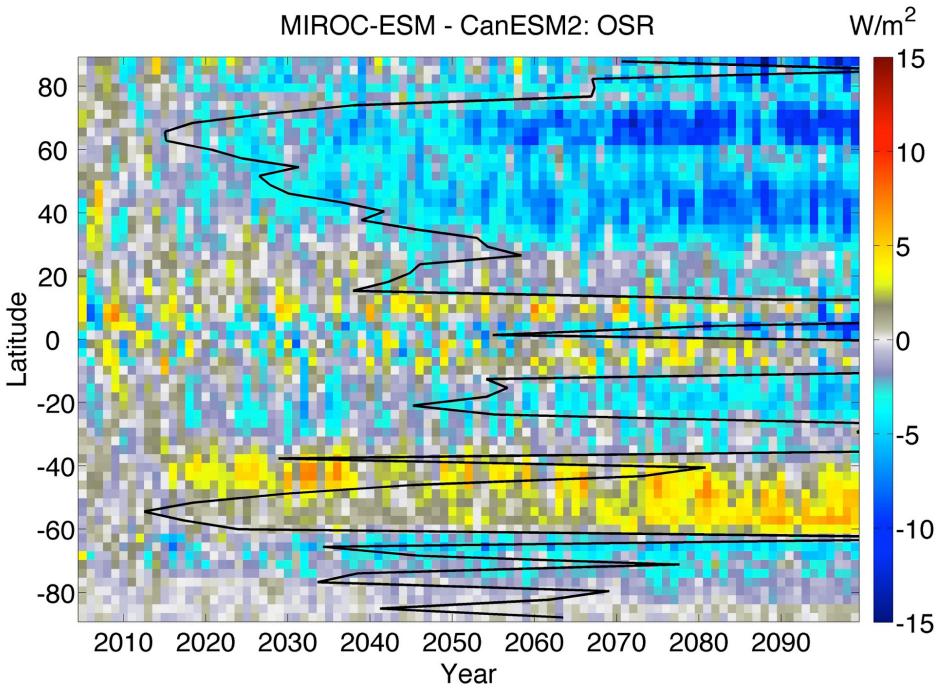




Model Differentiation: MIROC-ESM (4.7°) − CanESM2 (3.6°)

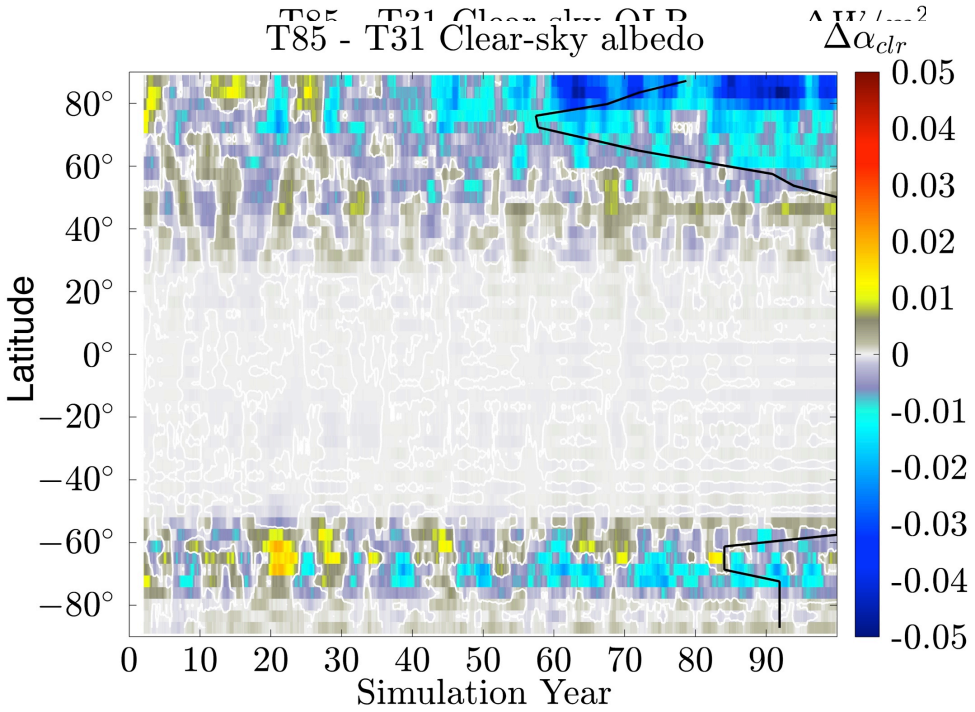
- MIROC-ESM and CanESM2 differ in ECS by 1°.
- Under RCP8.5, perfect broadband measurements starting in 2005 can begin to exclude one of these models with 20-25 years' of data.

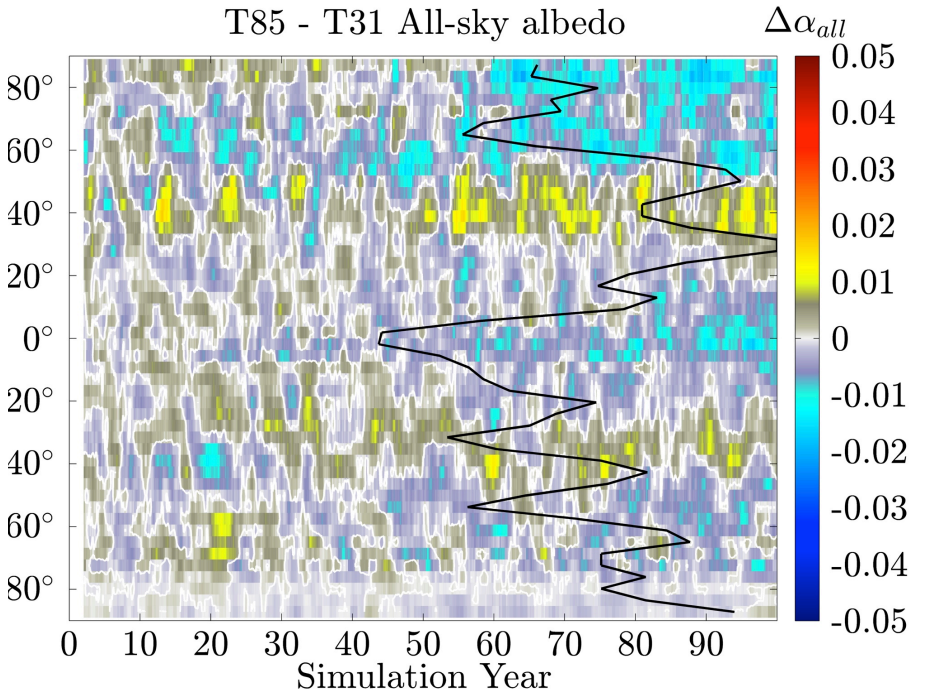




Model Differentiation: T85 CCSM3 (2.7°) – T31 CCSM3 (2.3°)

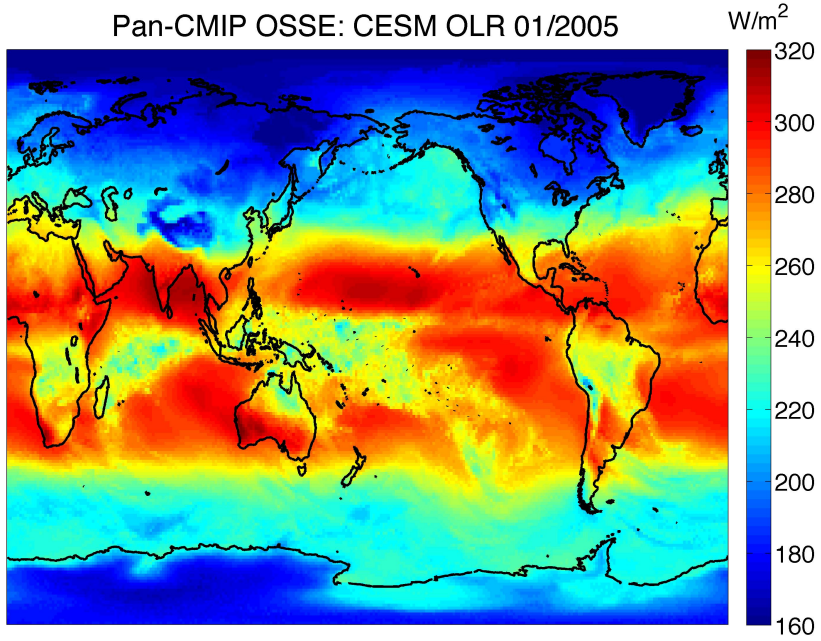
- Two resolutions of CCSM3 differ in ECS by 0.4°.
- Under RCP8.5, perfect broadband measurements starting in 2005 can begin to exclude one of these models with 20-25 years' of data.

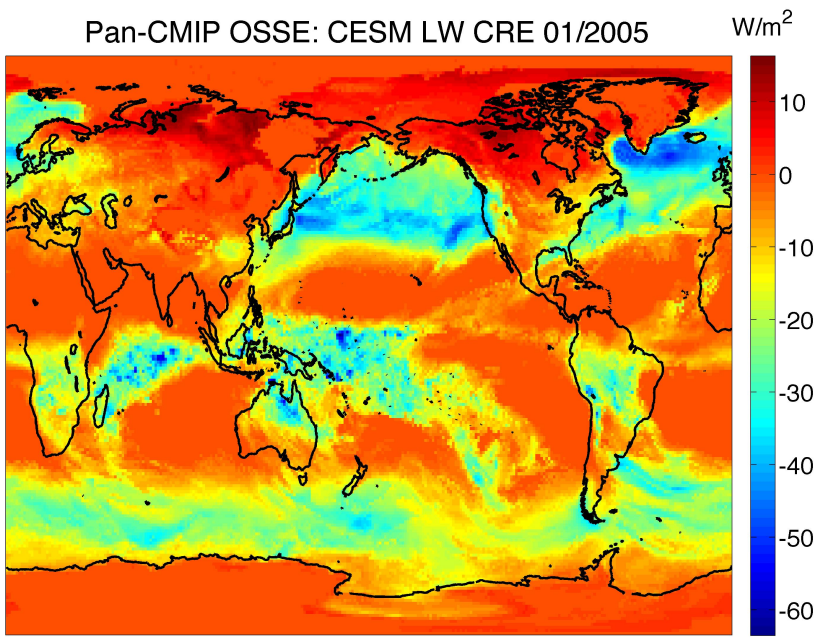




TOA Fluxes

- CMIP-model agnostic OSSE is mechanically working on NAS systems.
- Preliminary output of fluxes from CAM RT and MODTRAN show agreement in LW within 3 W/m^2 (clear-sky) and 10 W/m^2 (all-sky).
- More debugging on the timing system is still needed for the SW.

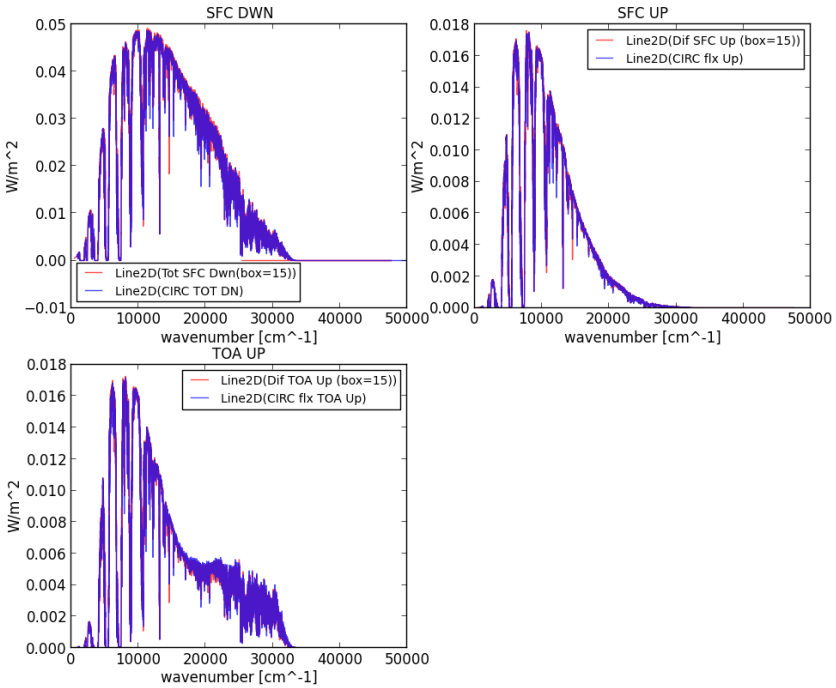




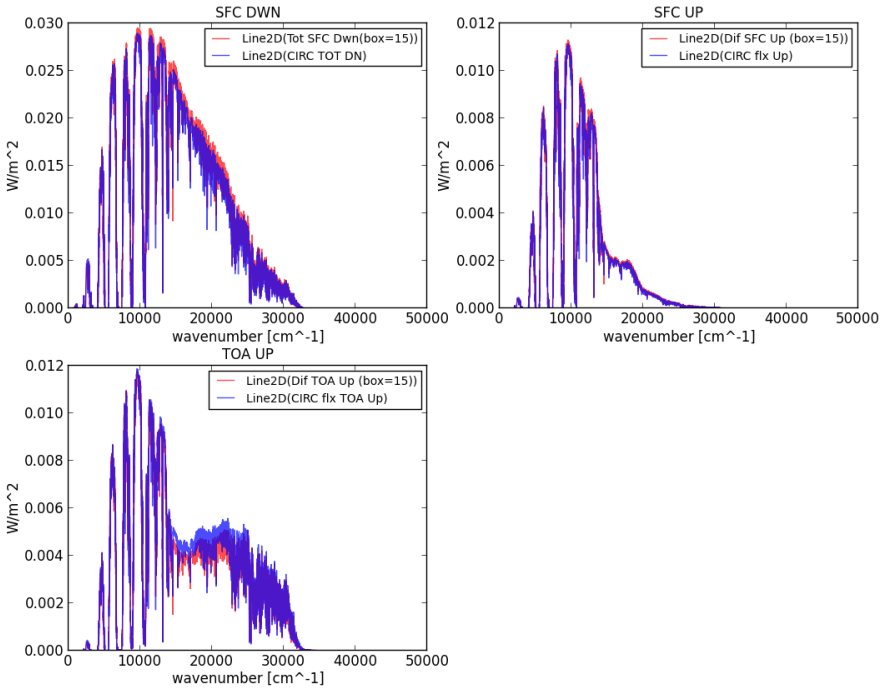
Benchmark Testing

- Multiple scattering line-by-line radiative transfer calculations (LBLRTM+CHARTS) coupled to a database of ice cloud optical properties enable versatile spectral flux calculations.
- NERSC and NAS resources take advantage of embarrassingly parallel nature of these calculations. Burst-buffer will address disk-limitations that hinder scaling.

CIRC Case 1 CHARTS, qsub runs 9/14/2015



CIRC Case 2 CHARTS, qsub runs 9/14/2015



Additional Opportunities with a Pan-CMIP OSSE

•The pan-CMIP OSSE produces radiometrically-rigorous radiative transfer calculations across the CMIP, thereby enabling additional science.

- Realistic evaluation of the spatial distribution of radiative forcing from greenhouse gases and aerosols across a multi-model ensemble in realistic all-sky conditions.

- Goal is to contribute to more realistic assessment of forcing for IPCC AR6.

•Recent 1M CPU-hour NASA supercomputing resources award for runs on Pleiades can enable this science.

Summary

- International collaboration with Imperial College and UMich partners yielding exciting science in the far-IR.
- A fully agnostic pan CMIP OSSE is now working.
  - Some additional testing and benchmarking still needed.
  - Preliminary time-series analysis suggests that CLARREO-like measurements will take less than 15 years' to exclude a model where ECS is off by 2.5°K/2xCO_2.
  - Some debugging is still necessary in the SW.
  - Integration of SW and LW PCRTM will then proceed.
- Additional scientific opportunities enabled by the pan-CMIP OSSE, especially for IPCC AR6.

Acknowledgements:
This research was supported by NASA grants NNH11AQ75I and NNH14ZDA001N-ACSCS. NERSC and NASA High-End Computing grants provided computational resources.